A compact UWB passive balun solution for cryogenic 2-13 ghz eleven feed for future wideband radio telescopes

A Compact UWB Passive Balun Solution for Cryogenic 2-13 GHz Eleven Feed for Future Wideband Radio Telescopes

Hasan Raza[1], Jian Yang[1] and Miroslav Pantaleev[2]
[1]Department of Signals and Systems, Chalmers University of Technology, S-412 96 Gothenburg, Sweden
hasan.raza@chalmers.se, jian.yang@chalmers.se
[2]Onsala Space Observatory, Chalmers University of Technology, S-412 96 Gothenburg, Sweden
miroslav.pantaleev@chalmers.se

***Abstract*— The decade bandwidth Eleven antenna can be considered to have either 4 differential ports or eight single-ended ports, and different ways of combining the eight ports are needed for different purposes and applications. This paper presents a new passive balun for the Eleven antenna and a way to integrate four of these baluns together with the antenna in such a way that the 4 differential ports reduce to 4 single-ended ports. The baluns are realized on printed-circuit-boards (PCB) that are located vertically to the ground plane on the rear side of it.**

Keywords- UWB Balun, Eleven Feed, compact UWB feeding network, UWB antenna.

I. INTRODUCTION

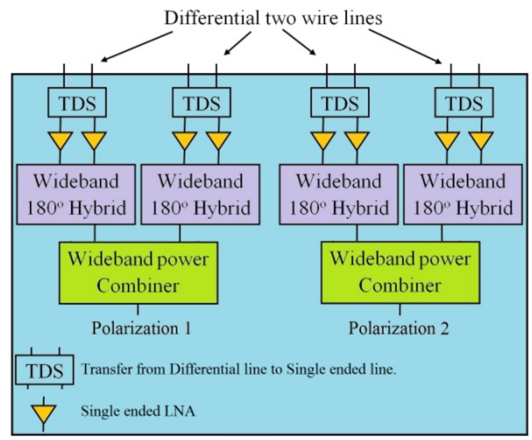
The Eleven antenna is a log-periodic dipole array antenna with decade bandwidth. Four log-periodic dipole array petals are placed over a ground plane in the dual polarized version. Due to the constant beamwidth with about 11 dBi directivity and fixed phase center over decade bandwidth, the Eleven antenna can be used as a feed for reflector antennas with high performance for ultra-wideband (UWB) radio telescopes [1]-[8].

The feeding network is a critical component in the design of the Eleven antenna, specially for high frequency applications, such as 1 – 10 GHz version for the Square Kilometer Array (SKA) project and the 2 – 14 GHz version for the Very Long Base line Interferometer (VLBI2010) projects. Due to the small physical size at the high frequencies, designing manufacturable and cost-effective feeding networks is a real challenge. Previous design of the feeding networks had some mechanical difficulties [8], where steel needles were used to form twin-wire transmission lines which made assembling a difficult task and therefore the required tolerance was not guaranteed by margin.

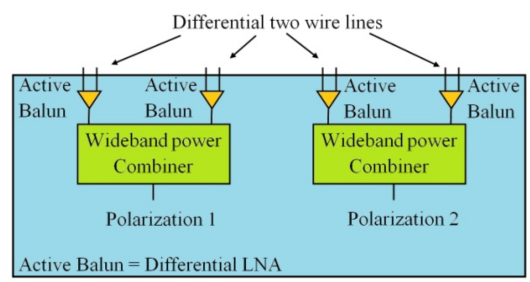
This paper presents new developments of different feeding solutions to different configurations of the Eleven feed by using only printed circuit board (PCB) technique. Therefore, the manufacturing tolerance can be minimized further to guarantee the performance, and production and assembling costs are reduced, too. Simulations and measurements presented in the paper show that the new feeding solutions provide a better performance than the previous one.

II. DIFFERENT CONFIGURATIONS OF THE ELEVEN FEED

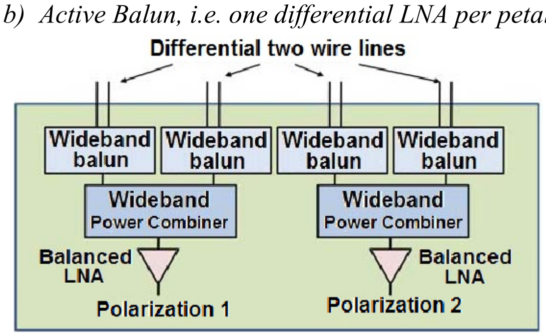
There are three different configurations for the Eleven feed for different scenarios integrated with low noise amplifier (LNA) for different purposes [8], which are shown in Fig. 1. Therefore, three compact feeding solutions using only PCB technique are proposed here.



a) Two 50 ohm LNAs and one 180^o hybrid per petal.



b) Active Balun, i.e. one differential LNA per petal.



c) Passive balun followed by power combiner.

Figure 1. Three configurations of the feeding network for the Eleven feed.

A. *Single Ended 8-port Solution*

A single ended 8-port feeding solution was presented in [8], where steel needles were used to form 200 ohm twin-wire transmission lines to connect the antenna on one side of the ground plane to microstrip board on the other side of the ground plane where tapered lines were used to transform the impedance to 50 ohm. Due to the small size, it is difficult to locate the steel needles and solder them on both sides of the ground plane with high accuracy. Here an improved design is proposed, see Fig. 2.

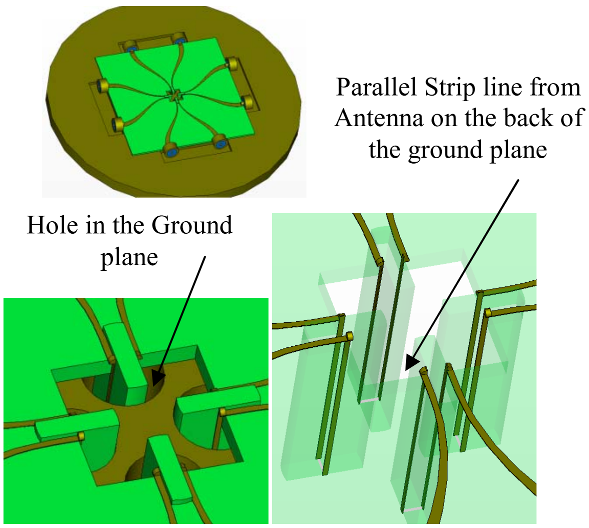


Figure 2. New design of the single ended 8-port solution.

Four vertical parallel strip lines on PCB boards from the antenna side (which in this case supposed to be from below the ground plane) passes the ground plane through four holes and soldered to the corresponding microstrip lines. This will form four pairs of odd mode coupled microstrip lines, with 200 Ω impedance. The dimensions of the parallel strip line and the microstrip line at the junction are matched so that a smooth transaction occurs without having introduces much loss. The coupled lines are gradually separated by tapering so as to get two separated uncoupled microstrip lines having 180^o phase difference. The simulated reflection coefficient and transmission from the balanced port to unbalanced port are shown in Fig. 3. Port 1 is the balanced port which connects the dipole arrays, and ports 2 and 3 are the corresponding 50 Ω microstrip unbalanced ports. Ideally S_{21} and S_{31} should be -3 dB due to the power split equally between ports 2 and 3, but because of mismatch factor, ohmic and radiation losses, S_{21} and S_{31} in the Fig. 3 get lower than -3 dB. Compared to the previous design, where the reflection and transmission coefficients were -12 dB and -4 dB, respectively, over 2 – 12 GHz band (shown in Fig. 12 in [8]), the reflection and transmission coefficients have improved by 1 dB and 0.5 dB, respectively, by the new design. From the figure, it can be concluded that the ohmic and radiation losses are only about 0.3 dB for the new design. In addition, the new solution has wider operating band than the previous one.

B. 200 ohm 4-port Solution

This design is for integrating the differential LNA as active balun with Eleven antenna [8]. The input port of the differential LNA is a coupled microstrip line with an odd mode characteristic impedance of 200 Ω whereas the output port is a coaxial cable with the characteristic impedance of 50 Ω. The new design of the 200 Ω 4-port solution is presented in Fig. 4.

Again four vertical parallel strip lines on a PCB board from the antenna side pass the ground plane through four holes and soldered to the corresponding microstrip lines. The distance between these microstrip line is gradually increase to make their output port align with the differential LNA port and have the 200 Ω differential impedance.

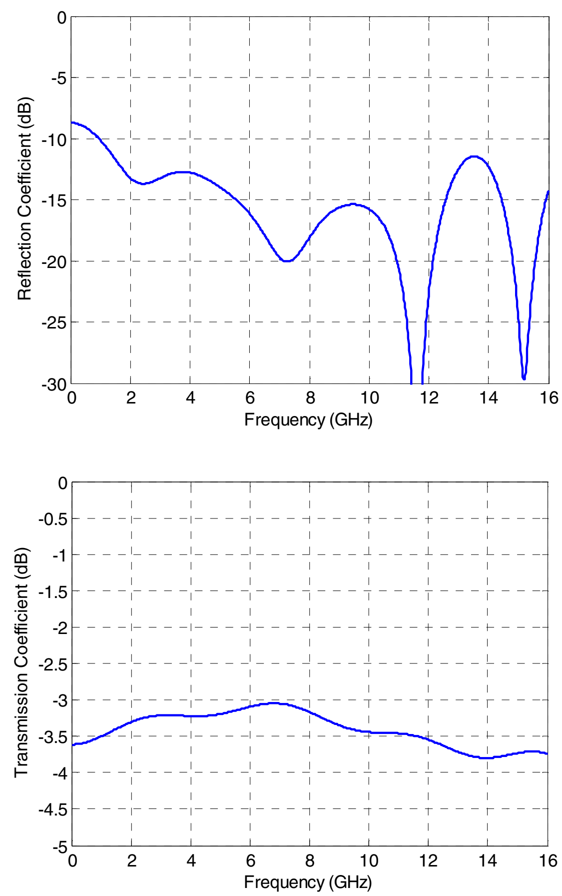


Figure 3. Simulated S-parameters of the single ended 8-port solution.

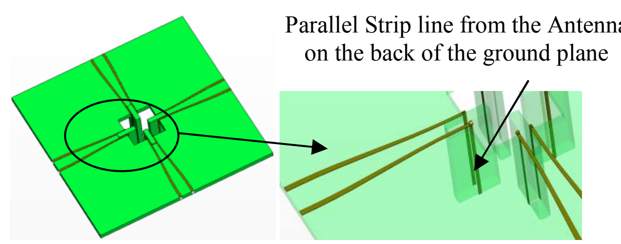


Figure 4. New design of 200 ohm 4-port solution.

Fig. 5 shows the simulated reflection and transmission coefficients for the feeding solution. Port 1 is the balanced port of log-periodic dipole array and port 2 and port 3 are the corresponding microstrip unbalanced port. It can be observed that this new design provides a below -12 dB reflection coefficient and less than -0.5 dB transmission loss up to 16 GHz. From this, we see that there is only 0.2 dB ohmic loss for the new design.

C. Passive Balun

Configuration of the passive balun feeding solution is shown in Fig. 1c. Due to the decade bandwidth requirement of the Eleven feed, a tapered microstrip line is an optimal solution [9]. The front and rear side of the basic design of the balun is shown in Fig. 6. The size of the twin balun is 50 x 50.87 [mm] on the 0.762 mm thick substrate material Rogers TMM3. Then, in the new design, all four UWB compact baluns are made on PCB boards and connected directly to the ports of the Eleven antenna petals on the other side of the ground plane through four holes on the ground plane, see Fig. 7. Then, two UWB passive power combiners and two wideband cryogenic single-ended LNAs can be integrated to the new balun solution for making two output ports, one for each polarization.

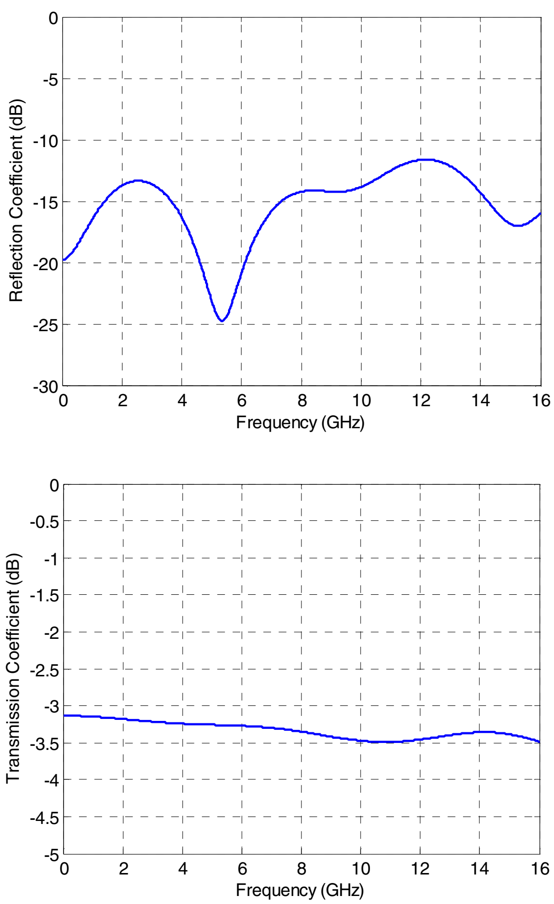


Figure 5. Computed S-parameters of the 200 Ω 4-port solution with 200 ohm loads on the 4 differential ports.

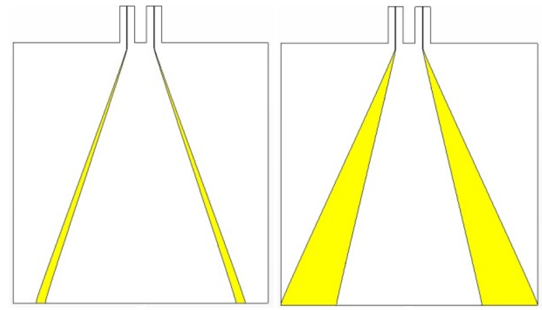


Figure 6. Geometry of the present twin tapered microstrip line balun shows the front (left) and rear (right) sides of the circuit board

The balanced output ports of each balun have the same impedance as that of the single petal input terminal of 200 ohms. This can be conveniently achieved within the available space constraints. It can be observe that this solution is very compact. Moreover, since the Eleven antenna has the two polarization channels, another two-balun arrangement is placed orthogonal to the previous one, see Fig. 8.

On the rear side of the Eleven antenna, all four baluns are enclosed in a shielded metal box, see Fig. 8. The shielded box is partitioned diagonally as well so that the balun can be placed inside each room to have a maximum isolation among baluns. In order to suppress the resonance introduced by the shielded metallic box, 1 mm thick ECCOSORB MCS absorbing sheet is used for cavity resonance reduction, which is placed on the inner side of the shielded metal box.

These baluns are also 200-to-50 ohms impedance transformers. The length of this transformer and the tapering of the conductors determine the lowest operating frequency, which is optimized in this work for 1.5 GHz.

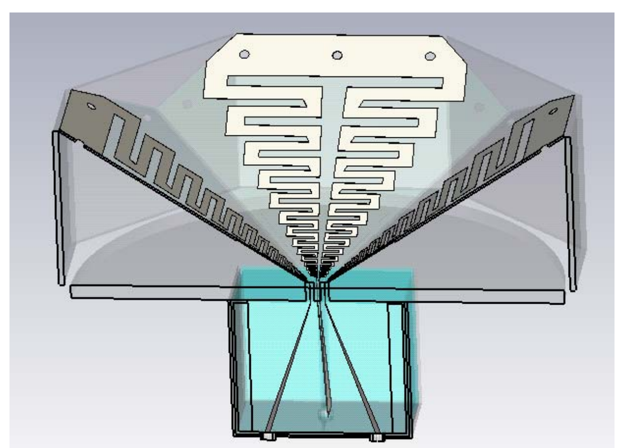


Figure 7. Integration of the balun with Eleven feed petals.

In order to confirm the performance of the new balun, a structure of two baluns in a back-to-back configuration has been manufacture and measured, see Fig. 9. Fig. 10 shows that the simulated and measured reflection and transmission coefficients of the back-to-back balun circuit. The reflection coefficient is below -10 dB for 2.5 – 16 GHz, which means that a single balun should have below – 12 dB performance. The measured transmission coefficient agree well with the simulated one, expect for some dips at a few frequency point. This may be caused by some resonance within the metal support frame, where there in final design should be some thin absorbing sheet to suppress the resonances. More investigation and measurements are in the progress.

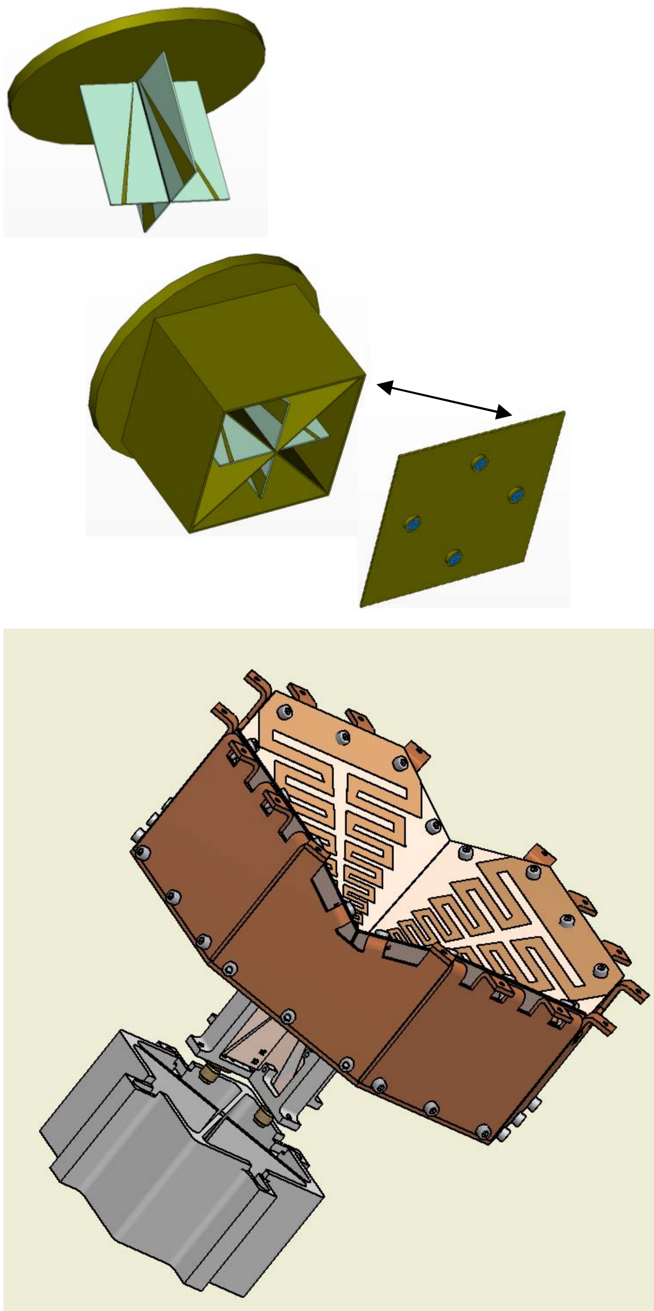


Figure 8. Arrangment of four baluns behind the ground plane for two polarization of Eleven Antenna.

III. Conclusion

New compact UWB passive balun for the decade bandwidth Eleven antenna has been presented, based on using four printed circuit boards located vertically to the ground plane on the back side of it. The passive baluns have promising performance, except for a deep resonance at 2.3 GHz. This could be specific for the measured back-to-back measurement situation, which will be known when the whole feed with integrated baluns has been measured. Such results will be presented at the conference.

Acknowledgement

This work has been supported by The Swedish Foundation for Strategic Research (SSF) within the Strategic Research Center CHARMANT and Pakistan's NESCOM scholarship program.

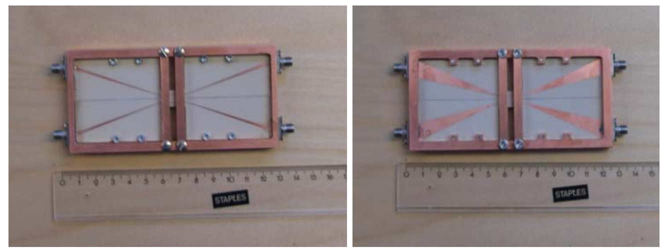


Figure 9. Tapered microstrip balun with back – to – back configuration.

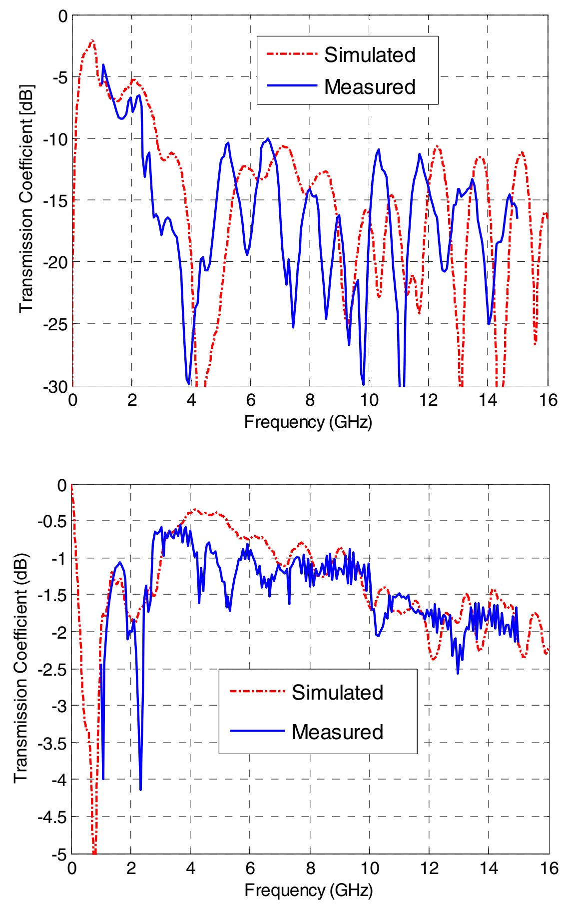


Figure 10. Simulated and Measured S-parameters of back-to-back balun.

REFERENCES

[1] R. Olsson, P.-S. Kildal and S. Weinreb, "The Eleven antenna: a compact low-profile decade bandwidth dual polarized feed for reflector antennas," *IEEE Trans. Antennas Propogat*., vol. 54, no.2, pp. 368-375, Feb. 2006.

[2] P.-S. Kildal, R. Olsson and J. Yang, "Development of three models of the Eleven antenna: a new decade bandwidth high performance feed for reflectors," *1st Eur. Conf. on Antennas Propagat. (EuCAP2006),* Nice, France, 6 - 10 November 2006.

[3] J. Yang, X. Chen, N. Wadefalk, P.-S. Kildal, "Design and realization of a linearly polarized Eleven feed for 1-10 GHz," *IEEE Antennas Wireless Propag. Lett.*, vol. 8, pp. 64-68, 2009.

[4] J. Yang and P.-S. Kildal, "Optimization of large log-periodic dual-dipole antenna by using genetic algorithm on embedded element in small logperiodic array," *3rd Eur. Conf. on Antennas Propagat. (EuCAP2009),* Berlin, 23 - 27 March 2009.

[5] J. Yang, D. Nyberg and J. Yin, "Impedance matrix of a folded dipole pair under Eleven configuration," *IET Microwaves Antennas Propagat*., vol. 4, no. 6, pp. 697-703, June, 2010.

[6] J. Yang, "On Conditions for Constant Radiation Characteristics for Logperiodic Array Antennas," *IEEE Trans. on Antennas Propagat*., vol. 58, no. 5, pp. 1521-1526, May, 2010.

[7] J. Yang, P.-S. Kildal, "Optimizing large log-periodic array by computing a small part of it," *IEEE Trans. on Antennas Propag. Special Issue on Antennas for Next Generation Radio Telescopes*, vol. 59, no. 3, March 2011.

[8] J. Yang, M. Pantaleev, P.-S. Kildal, B. Klein, Y. Karandikar, L. Helldner, N. Wadefalk,C. Beaudoin "Cryogenic 2-13 GHz Eleven feed for reflector antennas in future wideband radio telescopes," *IEEE Trans. on Antennas Propag. Special Issue on Antennas for Next Generation Radio Telescopes*, vol. 59, no. 3, March 2011.

[9] G. Engargiola, "Tapered Microstrip Balun for Integrating a low noise amplifier with a nonplanar log periodic antenna", *Review of Scientific Instruments*, vol. 74, No. 12, pp. 5197-5200, Dec. 2003.